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APPLICABILITY OF QUARRY SAND AS A FINE AGGREGATE IN THE PRODUCTION OF MEDIUM GRADE CONCRETE

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ABSTRACT
Partial and total replacement of fine aggregate in conventional concrete with quarry sand has been empirically conducted with the view too examining primarily the compressive strength of the resulting composite and possible utilization of quarry sand as fine aggregate in the production of medium grade concrete. The results of the study revealed that its specific gravity, bulk density, porosity, water absorption, silt content, the impact value and the aggregate crushing value showed satisfactory performance. The percentage replacement of natural river sand with quarry sand for a designed strength of 25N/mm^2 varied at intervals of 10% up to a maximum value of 100%. A total of 134 cubes of 150×150×150mm were cast and tested at 7, 14 and 28 days of hydration. Compressive strength increases with curing age in all the mixes. Compressive strength decreases with increase in percentage of quarry sand. Generally the compressive strength of concrete incorporating quarry sand attained strength above 23.71 N/mm^{2}which makes it a suitable aggregate for the production normal weight concrete.

KEYWORDS: Quarry sand, fine aggregate, concrete, compressive strength, mixes.

INTRODUCTION

The cost of producing dense concrete works has become prohibitive partly due to the soaring cost of aggregates. Umoh and Kamang (2005) posited that the use of concrete for various construction works has also led to the escalation of the cost of construction materials particularly cement and aggregates. Aggregate which occupy 70-75% of the total volume of concrete (Troxel *et al.,* 1968) has been one material which if alternatives are provided will bring down the overall cost of construction. In the face of the general increase in building activity and civil engineering construction particularly in the field of reinforced concrete and road construction, the consequent spectacular increase in the consumption of natural gravel and crushed rock aggregate is becoming expensive. These and other reasons have made the construction industry to consider the gradual utilisation of alternative materials for construction. Abalaka (2001), stated that, as aggregate is cheaper than cement, therefore it is economical to put as much of it and as little of cement in the production of concrete. Economy is definitely not the only reason for the importance of aggregate in concrete as it impacts considerable technical advantage to concrete in terms of higher volume, stability and better durability than cement paste alone (Neville 1981). It has been established that three-quarters of the volume of concrete is occupied by aggregate, its quality and quantity are therefore of considerable importance in concrete production.

This paper examines the use of quarry sand as a replacement of natural river sand as fine aggregate in the production of medium grade concrete. The idea of using quarry sand as an alternative aggregate was developed because granite which is the parent material is hard and dense and therefore can serve as an excellent aggregate material. Its use as a fine aggregate in concrete is expected to improve certain properties, such as the compressive strength, durability, strength development, workability and economy. The importance of the compressive strength of concrete is such that for structural design purposes, the compressive strength is the criterion for quality (Troxel *et al*., 1968).The use of some materials other than natural sand as fine aggregate in both concrete and mortar has been investigated. Among these materials are silt and kaolin waste by Banfill and Benson (1978), laterite by Lasisi *et al* (1990), waste Sancrete blocks by Kamang and Umoh (2005) and preliminary assessment of Quarry sand by Waziri and Mu'azu (2008). With the recent trend towards utilization of locally sourced building material so as to reduce construction cost and the availability of quarry sand from quarry sites across the country has brought about the research.

MATERIALS AND METHODS

The quarry sand was obtained from a quarry site in Gwoza, Borno State. The aggregates were thoroughly washed (to remove unwanted materials) and dried. The aggregates were graded in accordance with BS 812 part 1: 1975. The cement used in the study was the Ashaka brand of Ordinary Portland Cement (OPC). It's initial and final setting time was determined using BS 12: 1978. Water used for the tests was free from impurities such as silt, clay, acids, alkalis and other salts, organic matters and sewage. The aggregates were washed and then air dried in the laboratory for 48hrs to bring it to approximately saturated surface dry (SSD) condition, to reduce the effect of absorption. The natural sand used as fine aggregate was natural river sand belonging to zone one, and the coarse aggregate was quarried granite which met the requirements for the nominal size of graded aggregate.

The basic concrete mixtures were:

i. Concrete mix which is made up of crushed granite as coarse aggregate, natural sand as fine aggregate and cement.
ii. Concrete consisting of granite as coarse aggregate, quarry sand as fine aggregate and cement.
iii. Concrete consisting of granite as coarse aggregate, combination of River sand and quarry sand as fine aggregate and cement.

All the three basic mixtures were designed in each case to attain a characteristic strength of 25N/mm^2 (medium grade) at 28 days. The mix design used is the one published by the Department of Environment (1975). In the mix containing the combination of quarry sand and river sand as fine aggregate, the percentages of replacement of the natural river sand with the quarry sand was done by weight. The percentage of replacement varied at intervals of 10% up to maximum of 100%. Slump and compacting factor tests were performed on each batch in accordance with provisions of BS 1881 (1970). A total of 134 cubes of dimension 150mm×150mm×150mm were cast in three layers; each layer is vibrated for 1-3 minutes. The hardened specimens on removal from the moulds were immediately immersed in water and cured at 27 ± 2^oC and tested at the specified periods of 7, 14, and 28 days. Comprehensive strength tests were carried out using a universal compression testing machine. The compressive forces at the point of failure of the cubes were recorded. The average failure load from three cubes from each mix was used in estimating the compressive strength of the concrete for the mix.

RESULTS AND DISCUSSIONS

Particle Size Distribution

The result of the particle size distribution carried out on quarry sand in accordance with BS 812 part 1: 1975 is presented in table 1 and fig 1.

Table 1. Particle Size Distribution

Sieve size	Weight Retained (gm)	% Retained	Percentage Passing
4.75mm	85	8.5	91.5
3.35mm	125	12.5	79.0
2.36mm	135	13.5	65.5
1.18mm	215	21.5	44.0
4.25 μm	210	21.0	23.0
3.00 μm	59	5.85	17.2
150 μm	110	11.0	6.2
75 μm	40	4.10	2.1
Pan	16	1.65	0.4

From the result of sieve analysis, more than 90% of the aggregate passed through sieve 4.75mm which places the aggregate as fine aggregate as (BS882), and the assessment of the particle size distribution revealed that the aggregate is well graded. The result further revealed that the quarry sand falls within the grading limits of zone one fine aggregate and therefore suitable for use in concrete.

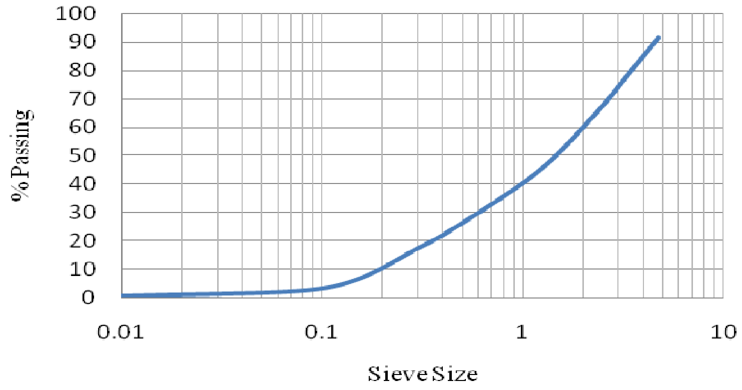

Fig 1. Particle Size Distribution

Characteristic Properties of Quarry-Sand
The characteristic properties of Quarry sand is presented in table 2.

Table 2: Properties of Quarry –Sand.

Apparent specific gravity	2.71%
Water absorption	9.15%
Loose bulk density	1520 kg/m^3
Compacted bulk density	1793kg/m^3
Porosity	15.2%
Silt content	7.21%
Aggregate Crushing Value (ACV)	34.5%
Aggregate Impact Value (AIV)	15.45%

The apparent specific gravity of quarry sand was found to be 2.71 (Table 2). This is higher than the value obtained by Olaoye and Kamang (1999) for pumice stone. The water absorption is found to be 0.15% (Table 2). Investigations also revealed the compacted and loose bulk densities of the aggregate as 1793kg/m^3 and 1520kg/m^3 respectively. From the test the porosity was also determined to be 15.2%. A porosity of 15.2% indicates that the mineral content rather than the voids greatly influenced the apparent specific gravity value. The silt content from the field penetration test is within the limit of 8% specified in BS 882 (1975). From the average crushing value test carried out on Quarry sand, a value of 34.5% was obtained. This is higher than the value obtained by Olaoye and Kamang (1999) for pumice stone, Okpala (1990) for palm kernel. It is also higher than the value for granite which has ACV of 28.6% (Neville 1981). The value obtained suggests a higher aggregate strength even though there is no explicit relation between the crushing value and compressive strength for any given aggregate, Neville (1981). The impact value of 15.45% indicates the adequacy of the aggregate to be used in concreting (BS 812: part 3 1975).

Slump and Compacting Factor test
The result for the slump and compacting factor for all mixtures are presented in table 3. In order to maintain the same workability range with the mixture containing quarry sand aggregate, higher water content was required (Umoh and Kamang 2005). This has been the reason for the gradual increase in water-cement ratio as the percentage of the quarry sand aggregate increased.

Table 3: Slump and Compacting Factor test.

% Quarry Sand Content	Actual W/C Ratio	Slump (mm)	Compacting Factor
0	0.50	43	0.87
10	0.52	46	0.89
20	0.54	52	0.91
30	0.55	40	0.84
40	0.56	54	0.89
50	0.58	55	0.88
60	0.60	55	0.89
70	0.62	56	0.87
80	0.65	58	0.88
90	0.67	58	0.89
100	0.68	59	0.91

The result of the workability test presented in Table 3 indicates that an increase in water- cement ratio increases both workability and compacting factor. This is expected since higher w/c ratio implies more mixing water and hence higher slump and compacting factor values. The higher water requirement in mixture containing quarry sand would be related to the amount of silt present which meant a greater specific surface to be wetted and lubricated. In all the mixtures, the values of the slump fall within the range of 30-60mm as stipulated by the Department of Environment (1975) for medium workability level.

Compressive Strength of quarry Sand concrete

The compressive strength development with hydration up to 28 days for all mix proportions is presented in Table 4. Typical plots of strength with ages of curing for the different water cement ratio have been provided in Figure 2.

Table 4: Compressive Strength test Results.

% Quarry Sand Content	Compressive Strength (N/mm^2)		
	7 days	14 days	28 days
0	16.82	23.72	27.71
10	16.24	23.05	26.90
20	15.06	22.75	26.43
30	15.01	22.16	25.77
40	14.64	21.15	25.42
50	14.22	20.09	25.07
60	13.53	18.12	24.76
70	13.24	17.06	24.42
80	12.54	16.03	24.12
90	12.13	15.15	23.98
100	11.24	14.23	23.71

* All values are average of three test results

The compressive strength continued to increase with age in all the mixture up to the 28 days tested. This continual increase in strength with curing age is an indication that there is no deterioration in the concrete within the 28-day test. The compressive strength decreases as the percentage of quarry sand increases. This can be attributed to the water absorption capacity of the quarry sand. This is manifested in the significant difference between the strength of conventional concrete (0% quarry sand) and that of 100% quarry sand.

Only the conventional concrete (0% Quarry sand) attained more than 60% of its 28day strength at 7 day. All other mix (10%-100% quarry sand) attain up to 50% of their 28day strength at 7 day. This revealed that concrete containing quarry sand cannot compare favourably with early strength development of conventional concrete mixture which are expected to attain up to 60% of their 28-day design strength at 7-day (Neville 1981). The American Standard for testing materials ASTM (1977) recommends a 28 days strength of at least 17N/mm^2 for structural light weight concrete and between 7 and 14N/mm^2 for masonry concrete. Based on this

recommendation, it would be deduced that quarry sand concrete could be adequate for both structural concrete and masonry concrete.

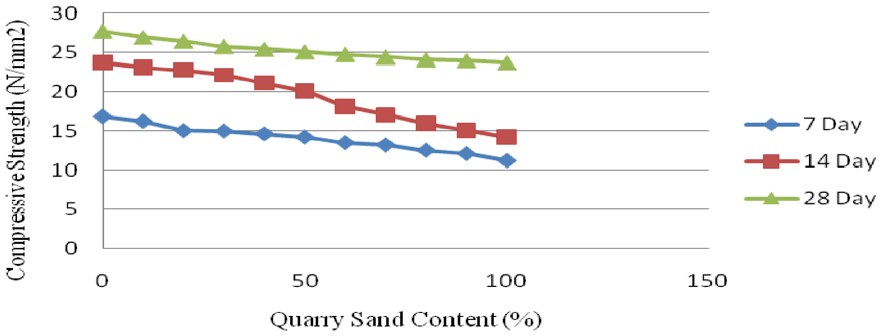

Fig. 2. Compressive Strength of mixes at different Hydration periods

CONCLUSION

From the study of the technical feasibility of using quarry sand as fine aggregate in the production of medium grade concrete. The following conclusions can be drawn:

1. The Quarry sand used has significant physical and chemical properties (specific gravity of 2.71, loose bulk density of 1520kg/m^3 and compacted bulk density of 1793kg/m^3 which classifies it as a light weight aggregate, it has a porosity of 15.2% which indicates that high porosity could have influenced the specific gravity of the material. The maximum value of the silt content present in the quarry sand was 7.21, and is below the maximum limit of 8% specified b BS 882 (1975).
2. The compressive strength increased with curing age for all the mixes but decrease with increasing percentages of quarry sand.
3. There is no noticeable deterioration observed since strength continued to increase as hydration progressed.
4. The research suggests the use of quarry sand as fine aggregate in concrete production.

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